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OPTICAL SOCIETY OF AMERICA

HANDBOOK OF OPTICS

CLASSICAL, VISION, & X-RAY OPTICS

• SECOND EDITION •

VOLUME III

MICHAEL BASS

JAY M. ENOCH • ERIC W. VAN STRYLAND • WILLIAM L. WOLFE

Don Bilderback

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Volume III
Classical Optics, Vision Optics, X-Ray Optics

Second Edition

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Michael Bass Editor in Chief

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Orlando, Florida

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and
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School of Optics / The Center for Research and Education in Optics and Lasers (CREOL),
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1 2 3 4 5 6 7 8 9 0 DOC/DOC 0 6 5 4 3 2 1 0

ISBN 0-07-135408-5

The sponsoring editor for this book was Stephen S. Chapman and the production supervisor was Sherri Souffrance. It was set in Times Roman by North Market Street Graphics.

Printed and bound by R. R. Donnelley & Sons Company.

This book was printed on recycled, acid-free paper containing a minimum of 50% recycled, de-inked fiber.

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sively is the magnetic circular dichroism in magnetic materials. However, the largest difference experimentally observed in absorption coefficients between the left- and the right-handed circular polarization is on the order of 1 percent, which is too small for any practical use as an X-ray circular polarizer.[13]

Fresnel rhomb is based on the principle that the reflected waves from the surface of a material can have different phase shifts between two othogonal linear states, σ and π. The X-ray analog of this occurs at a Bragg reflection from a crystal and arises from the difference in the intrinsic angular widths (Darwin widths) of the σ and the π diffracted waves.[14,15] The width for the π polarization is smaller than that for the σ polarization. Because of a continous phase shift of 180° from one side of the reflection width to the other, a difference in the phase shift can be obtained between the σ and the π polarizations if the angular position is selected to be near the edge of the angular width. Experimentally, a multiply bounced Bragg reflection is needed to make a ±90° phase shift. The phase shift is independent of the crystal thickness, but this method requires a highly collimated incident beam, about ⅒ of the reflection width, which is usually the limiting factor for its thoughput.[16]

The linear birefringence or double refraction effect relies on the difference in the magnitudes of the wavevectors of two orthogonal linear polarization states, σ and π, when a plane wave travels through a crystalline material. Because of this difference, a phase shift between the σ and the π traveling waves can be accumulated through the thickness of the birefringent material:[17]

$$\Delta = 2\pi(K_\sigma - K_\pi)t \tag{7}$$

where t is the thickness, and K_σ and K_π are the magnitudes of the wavevectors inside the crystal for the σ and π wavefields, respectively. When the phase shift Δ reaches ±90°, circularly polarized radiation is generated, and such a device is usually termed a *quarter-wave phase plate* or a *quarter-wave phase retarder.*

For X rays, large birefringence effects exist near strong Bragg reflections in relatively perfect crystals. Depending on the diffraction geometry, one can have three types of transmission birefringence phase retarders: Laue transmission, Laue reflection, and Bragg transmission, as illustrated in Fig. 3*b* and *c.* The Laue reflection type[9,18] works at full excitation of a Bragg reflection, while the Laue and the Bragg transmission types[19–22] work at the tails of a Bragg reflection, which has the advantage of a relaxed angular acceptance. In the past few years, it has been demonstrated that the Bragg-transmission-type phase retarders are very practical X-ray circular polarizers. With good-quality diamond single crystals, such circular phase-retarders can tolerate a larger angular divergence and their throughputs can be as high as 0.25, with a degree of circular polarization in the range of from 95 to 99 percent. The handedness of the circular polarization can be switched easily by setting the diffracting crystal to either side of the Bragg reflection rocking curve. There have been some excellent review articles[20–22] in this area and the reader is referred to them for more details.

25.5 CIRCULAR POLARIZATION ANALYZERS

Circular polarization P_3 of an X-ray beam can be qualitatively detected by magnetic Compton scattering[18] and by magnetic circular dichroism. In general, these techniques are not suitable for quantitative polarization determination because these effects are relatively new and because of the uncertainties in the materials themselves and in the theories describing the effects.

Two methods have been developed in the past few years for quantitative measurements of circular polarization in the X-ray regime. One is to use a quarter-wave phase plate to turn the circular polarization into linear polarization which can then be measured using a linear polarization analyzer (Fig. 4*a*), as described in the previous sections. This method is entirely analo-